

ORIGINAL ARTICLE

Chinese species of the genus *Prochiloneurus* Silvestri with description of a new species (Hymenoptera: Encyrtidae)

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Abstract Four species of the genus *Prochiloneurus* Silvestri, belonging to the family Encyrtidae of Hymenoptera, are reported from China. Among them, *P. stenopterus* **sp. nov.**, which is reared as the hyperparasitoid of *Phenacoccus solenopsis* Tinsley (Hemiptera: Pseudococcidae), an invasive mealybug to China, is reported as new to science. A key of the genus is provided for the recognition of the females of Chinese species. Notes on the parasitoid and hyperparasitoid of the mealybug *Phenacoccus solenopsis* are provided.

Key words *Prochiloneurus*, *Phenacoccus solenopsis*, parasitoid, hyperparasitoid, China, new species.

1 Introduction

The genus *Prochiloneurus* Silvestri, 1915 (Hymenoptera: Encyrtidae) is a world-wide genus and currently contains 29 species (Hayat, 2006b; Noyes, 2013). The genus is morphologically close to *Cheiloneurus* Westwood, 1833 and *Tineophoctonus* Ashmead, 1900 in the tribe Cheiloneurini, but can be separated from the latter genera by having the hypopygium reaching the apex of metasoma, the ovipositor distinctly exerted and the metasoma apically rounded, which not gradually tapered as other genera with an exerted ovipositor (Noyes & Hayat, 1984). However, there are some variation of morphological characters for generic distinction of *Prochiloneurus*, such as the presence or absence and the degree of development of the scutellar 'hair brush', in which the brush varies greatly in different species and shows some variation even within a single species (Hayat, 1981), and also as the antenna with the scape cylindrical or flattened and expended (Hayat, 2006b). Noyes and Hayat (1984) reviewed the genera of Indo-Pacific Encyrtidae and noted the distribution and species of *Prochiloneurus*, recorded the biology of the genus as the mainly hyperparasitoids on Coccidae and Pseudococcidae (Hemiptera) via other Encyrtidae and also recorded from Coccinellidae (Coleoptera). Hayat (1981, 2006a, b) reported the Indian species of *Prochiloneurus* and provided a key to the genus. For the China fauna of *Prochiloneurus*, three species, *P. io* (Girault), *P. nagasakiensis* (Ishii) and *P. nigricornis* (Girault), have been recorded until now (Noyes & Hayat, 1984; Xu & Huang, 2004; Zhang & Huang, 2004).

Phenacoccus solenopsis Tinsley (Hemiptera: Pseudococcidae) is an invasive mealybug, which was firstly reported damaging *Hibiscus* spp. from Guangzhou, Guangdong Province, China in 2008. Then the mealybug was found to damage the cotton in Hainan and Zhejiang Provinces (Wu & Zhang, 2009; Zhou *et al.*, 2010). According to the results of

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international pest risk analysis, *Phenacoccus solenopsis* is a high-risk invasive pest and has potential distribution to other areas in China (Wang *et al.*, 2009). Recently, the pest has been reported from 53 localities of various ecological zones of the globe (Ben-Dov *et al.*, 2013) and had caused severe economic damage to field crops, vegetables and horticultural ornamentals in India and Pakistan (Hodgson *et al.*, 2008; Arif *et al.*, 2009). The infested plants show general symptoms of distorted and bushy shoots, crinkled or twisted and bunchy leaves, and stunted plants that dry completely in severe cases. Though there are some insecticides to control the mealybug, biological control is an effective method. Since 2011, authors conducted surveys on the natural enemies of *Phenacoccus solenopsis* in Fujian Province. A primary encyrtid parasitoid, *Aenasius bambawalei* Hayat, and an undescribed species of *Prochiloneurus* as a hyperparasitoid were captured. Moreover, the species, *Prochiloneurus nagasakiensis* (Ishii), *Acerophagus coccois* Smith, *Aenasius bambawalei* Hayat (Encyrtidae) and *Allotropa phenacocca* Chen, Liu & Xu (Platygasteridae) were reported by Chen *et al.* (2011a, b) as the parasitoids of *Phenacoccus solenopsis* from Guangdong and Hainan Provinces.

In this paper, a new hyperparasitoid species, *Prochiloneurus stenopterus* **sp. nov.**, is described and illustrated.

2 Materials and methods

The parasitized specimens of mealybug, *Phenacoccus solenopsis*, were collected from the host trees in fields. In laboratory, only one of parasitized mealybugs was separately placed in a small glass tube for rearing the parasitoid, and the tubes were plugged tightly with cotton. The parasitoid or hyperparasitoid was to be recognized through examining of the host mealybug after parasitoid or hyperparasitoid emerged. If as a hyperparasitoid, there were remains of larva or adult primary parasitoid attached to the host mummy, whereas if as a parasitoid, there were no remains of primary parasitoid. After emergence, the parasitoids and hyperparasitoids were soaked in alcohol, or dried and mounted on cards, and were slide mounted for species identification following the methods described by Noyes (1982). Specimens on cards were measured and photographed using a MicroPublisher 5.0 RTV camera attached to a Zeiss Stemi 2000-C microscope with Auto-Montage software, whereas for slide mounted specimens the same camera and software were used but attached to a Zeiss Axioskop 40 microscope.

The terminology follows Noyes and Hayat (1984).

The following abbreviations are used:

C1, C2, *etc.*: clava segments 1, 2, *etc.*;

F1, F2, *etc.*: funicle segments 1, 2, *etc.*;

OCL: distance between the posterior ocelli and occipital margin;

OOL: distance between a posterior ocellus and eye margin;

POL: distance between the posterior ocelli;

T1, T2, *etc.*: gastral tergites 1, 2, *etc.*

Specimens studied and type materials are deposited in the following collections:

BMNH: Natural History Museum, London, British;

FAFU: Fujian Agriculture and Forestry University, Fuzhou, China;

IAES: Imperial Agricultural Experiment Station, Japan;

IZCAS: Institute of Zoology, Chinese Academy of Sciences, Beijing, China;

USNM: United States National Museum, Washington, D.C., U.S.A.;

ZJU: Zhejiang University, Hangzhou, China.

3 Taxonomy

Genus *Prochiloneurus* Silvestri, 1915

Prochiloneurus Silvestri, 1915: 350. Type species: *Prochiloneurus pulchellus* Silvestri, by monotypy and original designation.

Achrysopophagus Girault, 1915: 89. Type species: *Achrysopophagus oviductus* Girault, by original designation. Synonymized by Viggiani, 1966: 91.

- Parachrysopophagus* Agarwal, 1965: 65. Type species: *Achrysopophagus insolitus* Alam, by original designation (as subgenus of *Achrysopophagus*).
- Neoprochiloneurus* Viggiani, 1966: 95. Type species: *Prochiloneurus bolivari* Mercet, by monotypy and original designation. Synonymized by Noyes, 1978: 222.
- Prochiloneuroides* Hayat, Alam & Agarwal, 1975: 61. Type species: *Prochiloneurus comperei* Viggiani, by original designation. Synonymized by Hayat, 1981: 22.

Description. Female. Body robust or elongate; frontovertex narrow, usually less than 1/4 head width; occipital margin more or less sharp, but without sharp carina; ocelli usually forming an acute angle. Antennal scrobes often dorsolaterally margined by a ridge; antenna with scape subcylindrical or flattened and expended; funicle 6-segmented; clava 3-segmented, apically obliquely truncated. Mandible with three teeth. Dorsum of mesosoma moderately convex; mesoscutum with striated or scaly reticulations and usually with distinct silvery white setae. Scutellum usually with sculpture striated and apically with a tuft of bristles. Fore wing with an infusate pattern, apex of wing always hyaline, the inner margin of the hyaline area always curved and more or less subparallel to wing margin at apex; filum spinosum present; lineae calvae not interrupted posteriorly; marginal vein more or less five times longer than wide; postmarginal vein and stigmal vein short, apically connected by a naked, hyaline streak. Cercal plates situated in basal half of metasoma; metasoma apically rounded or transversely truncated; hypopygium reaching apex of metasoma; ovipositor distinctly exerted (Zhang & Huang, 2004). Male. Frontovertex about 1/3 width of head; facial impression never margined by a transverse facial ridge at top of antennal scrobes. Antennal scape somewhat flattened; pedicel short; funicular segments with whorls of long hairs; clava entire. Forewing hyaline; marginal vein more or less twice longer than wide; postmarginal vein and stigmal vein long (Zhang & Huang, 2004).

Biodiversity and distribution. About 29 species in world, cosmopolitan (Noyes, 2013); 3 species from China, *Prochiloneurus io* (Girault), *P. nagasakiensis* (Ishii) and *P. nigricornis* (Girault) (Xu & Huang, 2004; Zhang & Huang, 2004; Noyes, 2013).

Hosts. The species of *Prochiloneurus* are the mainly hyperparasitoids on Coccidae and Pseudococcidae (Hemiptera) via other Encyrtidae (Hymenoptera), and also recorded from Coccinellidae (Coleoptera) (Noyes & Hayat, 1984; Xu & Huang, 2004; Zhang & Huang, 2004; Hayat, 2006b).

Key to the species of *Prochiloneurus* (females) from China

1. Body mostly yellow to brown and dark brown. Fore wing short and narrow, not projecting beyond apex of metasoma *P. stenopterus* sp. nov.
Body mostly dark metallic green. Fore wing projecting beyond apex of metasoma 2
2. Antenna with flagellum uniformly black *P. nigricornis* (Girault)
Antenna with funicle pale white and clava dark to black 3
3. Scutellum with a tuft of black bristles near apex *P. nagasakiensis* (Ishii)
Scutellum with scattered hairs near apex *P. io* (Girault)

3.1 *Prochiloneurus io* (Girault, 1920)

Achrysopophagus io Girault, 1920: 187. Holotype female, Philippines (Manila) (reared from *Pseudococcus citri* on bamboo) (USNM).

Prochiloneurus io: De Santis, 1979: 11, 225. New combination for *Achrysopophagus io* Girault.

Material examined. 1 female, China, Guangxi, Shangsi, 10 June 2000, leg. Chao-Dong Zhu (IZCAS).

Hosts. Pseudococcidae: *Heliococcus* sp., *Nipaecoccus vastator*, *Nipaecoccus viridis*, *Planococcus citri*, *Pseudococcus citri* (Herting, 1972; Trjapitzin, 1989; Noyes & Hayat, 1994; Thompson, 1954).

Distribution. China, Philippines, Iraq, Puerto Rico (Zhang & Huang, 2004; Noyes & Hayat, 1994).

Comments. The species is characterized by following: body dark metallic green; antenna dark to black, except funicle segments, apex of scape broadly, distal two-thirds or less of the pedicel pale white; scutellum with scattered hairs near the apex, not forming a distinct tuft and fore wings with an infusate pattern, apex of wing broadly hyaline, base of wing also infusate.

3.2 *Prochiloneurus nagasakiensis* (Ishii, 1928)

Cheiloneurus nagasakiensis Ishii, 1928: 145. Holotype female, Japan (Nagasaki) (reared from *Pseudaococcus* sp. on citrus trees) (IAES).

Achrysopophagus nagasakiensis (Ishii): Tachikawa, 1956: 144. New combination for *Cheiloneurus nagasakiensis* Ishii.

Prochiloneurus nagasakiensis: Trjapitzin, 1968: 116. New combination for *Cheiloneurus nagasakiensis* Ishii.

Material examined. 1 female, China, Beijing, Botanical Garden, 29 August 1999, leg. Yan-Zhou Zhang (IZCAS); 2 females, China, Zhejiang, Huangyan, 25 June 1981, leg. Su-E Xu, ex. *Pseudococcus citricola* on citrus (ZJU).

Hosts. Pseudococcidae: *Pseudococcus citricola*, *Paracoccus flavidus*, *Phenacoccus pergandei*, *Planococcus kraunhiae*, *Pseudococcus* sp., *Phenacoccus solenopsis* (Xu & Huang, 2004; Chen *et al.*, 2011a). Coccidae: *Pulvinaria kuwacola* (Xu & Huang, 2004).

Distribution. China (Zhejiang, Guangdong), Thailand, Japan, Russia (Xu & Huang, 2004; Chen *et al.*, 2011a; Noyes & Hayat, 1994; Trjapitzin, 1989).

Comments. *P. nagasakiensis* is characterized by following: body dark metallic green; antenna dark to black, except funicle segments, apex of scape and apex of pedicel pale white; scutellum with scattered hairs near the apex, not forming a distinct tuft and fore wings with an infusate pattern, apex of wing broadly hyaline.

3.3 *Prochiloneurus nigricornis* (Girault, 1920)

Achrysopophagus nigricornis Girault, 1920: 187. Holotype female, Philippines (USNM).

Prochiloneurus nigricornis: Noyes & Hayat, 1984: 327. New combination for *Achrysopophagus nigricornis* Girault.

Material examined. 1 female, deposited in BMNH.

Hosts. Pseudococcidae: *Planococcus citri*, *Pseudococcus lilacinus*, *Pseudococcus citri* (Noyes & Hayat, 1994; Baltazar, 1966).

Distribution. China (Hongkong), Philippines (Noyes & Hayat, 1984; Xu & Huang, 2004).

Comments. *Prochiloneurus nigricornis* was originally recorded from Hongkong, China by Noyes & Hayat (1984). It is characterized by the following characters: body dark metallic green, antenna black except pale dusky distal half or more of the scape; fore wings broader than *P. io*, colour of wings about same as in *P. io* but the apex much less broadly hyaline; scutellum with a tuft of black bristles near the apex; legs with the fore coxa, femur and tibia conspicuously enlarged and compressed, much more enlarged than *P. io*.



Figs 1–3. *Prochiloneurus stenopterus* sp. nov. (female). 1. Dorsal view. 2. Ventral view. 3. Lateral view. Scale bars = 1 mm.

3.4 *Prochiloneurus stenopterus* sp. nov. (Figs 1–8)

Female. Body length (excluding exerted part of ovipositor) 1.65 mm (0.30 mm). Head brownish to brown; eyes dark to black; mandible dark brown apically. Antenna with radicle brown; scape basal about 3/4 brownish to brown, apical 1/4 pale white except apex brown; pedicel brown to dark brown; funicle pale white; clava dark brown to black. Pronotum brownish to brown, posteriorly with a dark brown band; mesoscutum brownish to brown, with short and dark brown bands on posterior sides; axilla and scutellum yellow; metanotum and propodeum pale white; mesopleuron pale white; mesosoma sterna pale yellow to brown yellow expect prosternum brown. Fore wing with base and slightly more than apical half infusate, area near to the middle of wing and distad of venation hyaline; submarginal vein pale yellow to



Figs 4–8. *Prochiloneurus stenopterus* sp. nov. (female). 4. Fore wing. 5. Postmarginal and stigmal veins of fore wing. 6. Antenna. 7. Pronotum, mesonotum, scutellum and axilla. 8. Apex of metasoma and ovipositor. Scale bars= 100 μm.

brownish except apex pale white, other veins infusate; setae on submarginal and stigmal veins brownish and setae on other veins brown to dark brown; setae on infusate area of wing disc brownish, on hyaline area pale white, on delta area below marginal vein dark brown, and on basal cell brownish respectively. Hind wing hyaline. Legs pale white, except all tibiae and tarsi brownish yellow, hind femora apically and all claws brown. Metasoma brown to dark brown, except apex mostly pale yellow to brownish. Ovipositor with exerted part brownish yellow.

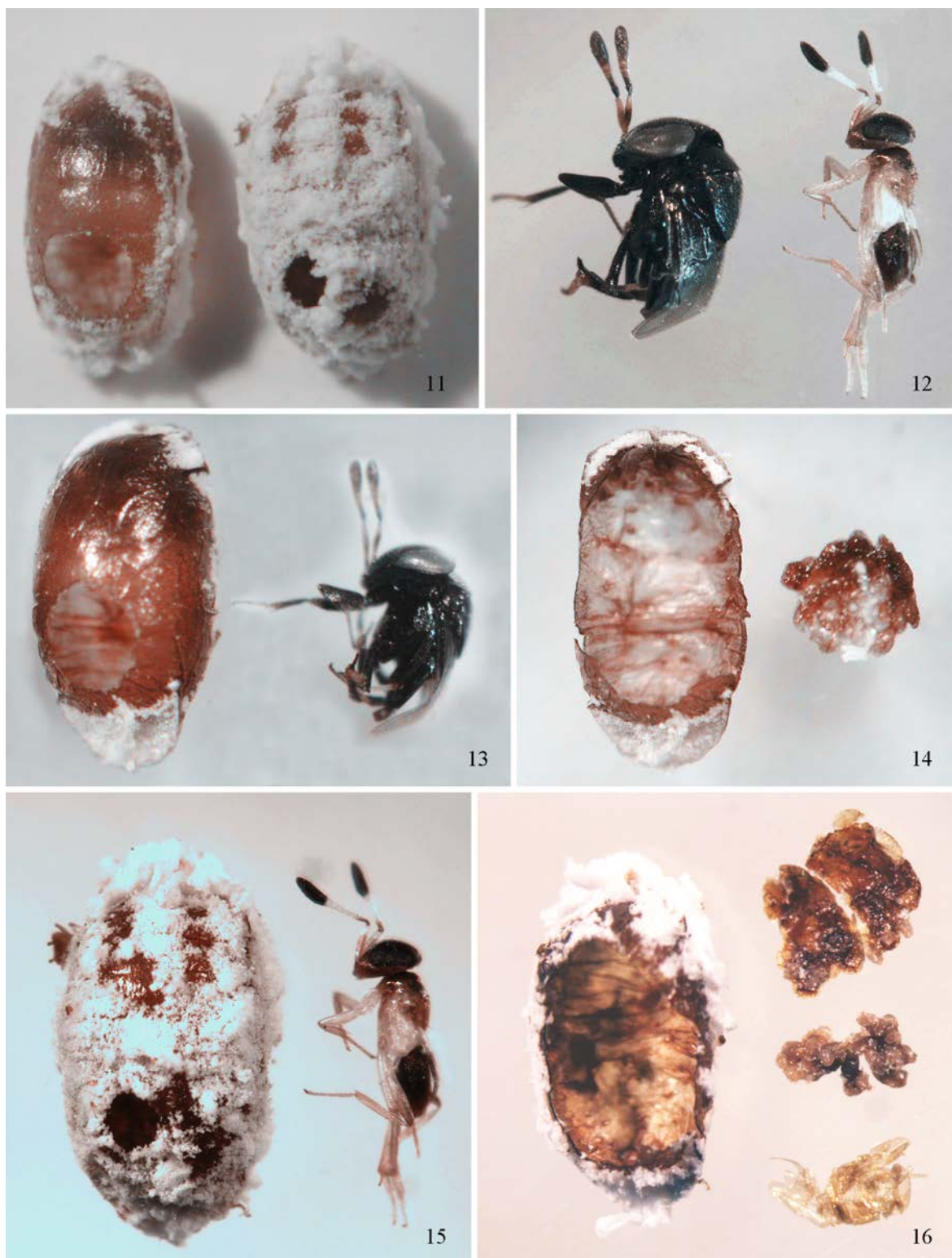
Head. Head large, wider than mesoscutum, 1.63 times as wide as long in dorsal view and 0.86 times as wide as high in facial view; frontovertex about 0.19 times as wide as head, with fairly coarse, reticulate sculpture; eyes large, almost reaching occipital margin; ocelli forming an angle of about 60°; POL, OOL and OCL about 1.2, 0.4 and 3 times diameter of anterior ocellus respectively; mandible with three teeth; antennal torulus close to mouth margin, antennal groove distinct. Antennal formula 1163; scape cylindrical, 5.66 times as long as wide; pedicel 2.59 times as long as wide, distinctly longer than each of funicle respectively; funicle with segments gradually wider, relative length: width of F1–F6 as 36.8:34.2, 31.2:37.9, 28.9:40.0, 31.3:43.9, 33.9:50.4, 35.2:70.0 respectively; clava expended and distinctly oblique ventrally, longer than funicle, C1–C3 with 10, 13 and 8 short linear sensilla respectively.

Mesosoma. Mesosoma slightly shorter than metasoma; pronotum, mesoscutum, axilla and scutellum with fine raised reticulate sculpture; pronotum relatively long and almost truncated in front, covered with dense, moderately stout setae; mesoscutum 0.63 times as long as wide, with dense fine setae and a line of 5 short black setae on the middle of posterior margin; axillae triangular, with fine setae, anteromedial angles close but not touching; scutellum 1.01 times as long as wide, shorter than mesoscutum, with dense fine setae and 5 long dark setae on the middle of subapical margin, not forming a distinct tuft; metanotum medially concealed under posterior margin of scutellum; propodeum appearing as a transverse strip, 6.20 times as wide as long. Fore wing about 3.32 times as long as wide, shortened and narrow, not projecting beyond the apex of metasoma; costal cell with a line of fine setae close to the anterior margin; basal cell with about 21 setae and a few fine setae; hyaline area near to the middle of wing with numerous fine setae, infusate area outside of linea calva with numerous short setae, hyaline streak from distad of venation to apical margin of wing with short fine setae; delta area below marginal vein with about 55 coarse setae and a few fine setae distally; submarginal vein with about 10 bristles; parastigma, marginal and postmarginal veins with about 31 setae in 2 to 3 rows, and 1 long bristle on distad of postmarginal vein; submarginal vein including parastigma 2.19 times length of marginal vein; marginal vein 2.83 times as long as stigmal vein and 4.33 times length of postmarginal vein; stigmal vein about 1.53 times as long as postmarginal vein, and 0.29 times as long as combined length of marginal and postmarginal veins.

Metasoma. Metasoma with apex blunt, about 1.52 times as long as wide, about 1.02 times as long as mesosoma; all tergites bare and reticulate laterally; cercal plate located at less than basad half of metasoma, with three long bristles and one short bristle; hypopygium slightly projecting beyond apex of metasoma. Ovipositor long and distinctly projecting beyond apex of metasoma, the length of ovipositor and its projecting about 1.14 times and 0.43 times as long as metasoma, and about 1.59 times and 0.59 times as long as mid tibia, third valvula 0.8 times as long as second valvifer and 0.71 times as long as mid tibia, respectively.



Figs 9–10. *Prochiloneurus stenopterus* sp. nov. (female). 9. Pupa, taken outside the host mummy. 10. Adult female, emerging outside the host mummy.



Figs 11–16. Comparison of *Aenasius bambawalei* (primary parasitoid) and *Prochiloneurus stenopterus* **sp. nov.** (hyperparasitoid) (females). 11. Host mummy, big emergence hole of *A. bambawalei* (left) and small emergence hole of *P. stenopterus* (right). 12. *A. bambawalei* (left) and *P. stenopterus* (right). 13. *A. bambawalei* (left) and its host mummy (right). 14. Dissected host mummy of *A. bambawalei* (left) and remains of host mealybug body attached (right). 15. *P. stenopterus* (right) and its host mummy (left). 16. Dissected host mummy of *P. stenopterus* (left), remains of host mealybug body (right, top), primary parasitoid larva (right, mid) and exuviae of *P. stenopterus* (right, bottom).

Pupa. In dorsal view head brownish to brown; eyes dark to black. Pronotum and mesoscutum brown to dark brown, axilla, scutellum, metanotum and propodeum yellow to brownish yellow; Metasoma brown to dark brown, except apex pale yellow to brownish. When developed well, the pupa outside the host mummy could also emerge to the adult (Figs 9–10).

Male. Unknown.

Holotype female (on slide), China, Fujian, Fuzhou, Jinshan (26°5'14.98" N, 119°14'2.89" E), September 2011, leg. Meng-Qin Huang, ex *Phenacoccus solenopsis* Tinsley on *Hibiscus rosa-sinensis* L., deposited in FAFU. Paratypes: 2 females (1 slide, 1 card), same data as holotype; 4 females (on cards), China, Fujian, Fuzhou, Jinshan, November 2013, leg. Yuan Gao, ex *Phenacoccus solenopsis* Tinsley on *Wedelia chinensis* (Osbeck.) Merr., all deposited in FAFU.

Host. Hyperparasitoid on *Phenacoccus solenopsis* Tinsley (Pseudococcidae) probably via *Aenasius bambawalei* Hayat (Encyrtidae) on *Hibiscus rosa-sinensis* L. and on *Wedelia chinensis* (Osbeck.) Merr.

Biology. The parasitized mealybugs was separately placed in a small glass tube in laboratory for rearing in order to recognize the primary parasitoid or hyperparasitoid. After the primary parasitoid or hyperparasitoid emerging, each host mummy was carefully dissected. For the primary parasitoid *Aenasius bambawalei*, the emergence hole was large and only the remains of host mealybug body was found attached the host mummy. Meanwhile, for the hyperparasitoid *P. stenopterus* **sp. nov.**, the emergence hole was small, and the remains of host mealybug body, primary parasitoid larva and exuviae of *P. stenopterus* **sp. nov.** were found attached the host mummy (Figs 9–16), of which the primary parasitoid is probably *Aenasius bambawalei*, because it is the major primary parasitoid by a large population associated with mealybug *Phenacoccus solenopsis* in Fuzhou. The recognition of the primary parasitoid or hyperparasitoid is important for biological control of the mealybug *Phenacoccus solenopsis*.

Distribution. China (Fujian).

Etymology. The specific name, *stenopterus*, means the fore wing distinctly short and narrow.

Comments. *Prochiloneurus stenopterus* **sp. nov.** is similar to *P. albifuniculus* (Hayat *et al.*, 1975) as follows: body mostly yellow to brown and dark brown; antenna with funicle pale white and clava dark brown to black; scutellum subapically with a few long dark setae that do not form a tuft of bristles; fore wing with infusate patch. However, by examining specimens of *P. albifuniculus* (Holotype, B.M.TYPE, HYM S.3352, deposited in BMNH), the new species can be distinguished from the latter in the following characters: head and pronotum distinctly brownish to brown (yellow in *P. albifuniculus*); pronotum with black setae and a dark brown band posteriorly (without in *P. albifuniculus*); scutellum and axillae with brownish setae (pale white in *P. albifuniculus*); antenna with scape basally 3/4 brownish to brown, apical 1/4 pale white except apex brown (brownish except apex pale white in *P. albifuniculus*); fore wing shortened and narrow, not projecting beyond the apex of metasoma (projecting beyond the apex of metasoma in *P. albifuniculus*), with base and slightly more than apical half infusate, area near to the middle of wing hyaline (in *P. albifuniculus*, area from about 1/3 to 5/6 infusate, and from about 5/6 to apical margin hyaline, and the apical hyaline area distinguishable into two areas: a semicircular area adjacent to infuscation with transparent setae, and distad of this band to apex with brown setae), and with a hyaline streak just from distad of venation to apical margin (to the semicircular pale area in *P. albifuniculus*).

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